Model for the Monitoring of Competences of the PISA Test in Peru under a B-Learning Approach

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***Abstract*—The quality of secondary education in Peru is one of the lowest in South America, as evidenced by the PISA 2018 evaluation. For this reason, we propose a model based on a B-Learning approach to monitor the competencies of the PISA test in Peru. The model is made up of 4 phases: (i) Selection of the methodology and technique, (ii) Design of the study material, (ii) Design of evaluations and (iv) Design of the web application. Three experiments were carried out to validate the proposal, where the "usability" was evaluated with a group of teachers and students, and with another group of students, the effect of the application on their "performance". The results showed that 73.3% of teachers and 80.7% of students found the application "very good". In addition, the results of the efficacy validation have shown that the application is effective in increasing the performance of students in the areas evaluated by at least 40%.**

I. INTRODUCTION

The Program for International Student Assessment (PISA) test is an evaluation developed by the Organization for Economic Cooperation and Development (OECD) [1] that is carried out every 3 years and has the purpose of evaluating the performance of 15-year-old students in mathematics , reading skills and science mainly, classifying performance in levels according to the area, but sharing a base line that is level 2.

Peru has participated in this test since 2000 and has shown a higher growth margin compared to other South American countries. Even so, the scores of the PISA results provided by the MINEDU in 2018 show that more than 50% of the students do not reach the development of competencies at level 2, that is, more than half of the high school students who are about to graduate have not developed them minimally the main competencies evaluated. There is an exception and it’s the result on the financial education test, where only 46.5% have not reached level 2, which, however, it is still a negative sign [2].

It has been shown that these digital tools are more attractive and have a greater influence on students and that, in the same way, the use of digital platforms facilitates the development of academic skills [3]. Iosifides et al. proposed the exposure of IoT elements to encourage students' interest in STEM, since they have identified that, despite the increase in job opportunities related to technology, the environment does not favor or promote students' interest in careers. of STEM [3]. She, Lin & Huang utilized the PISA assessment parameters to identify the critical points that caused poor student performance [4]. Sánchez & López presented the use of a questioning software that executes a serious game to strengthen the performance of students in the areas of reasoning [5]. These works have proven successful in their respective contexts; however, the context of Peru needs an application of this knowledge appropriate to cultural differences.

On the other hand, a B-Learning approach has been shown to be effective in increasing students' knowledge through virtual activities in applications in a supervised environment [6]. The authors proposed various functionalities to carry out the monitoring and evaluation in Economics in students of the University of Belgrade, Buenos Aires.

For this reason, we propose a model based on a B-Learning approach to monitor the competencies of the PISA test. This model will allow students to learn with the guidance of their tutor but also ensure they are fulfilling an international standard level in their competence development. The design of the model is made up of 4 phases: (i) Selection of the methodology and technique. (ii) Design of the study material, (ii) Design of evaluations and (iv) Design of the web application. For this purpose, 2 experiments were carried out to evaluate the usability of the developed application and 1 additional experiment to measure the effects on student performance.

This document is organized into different sections. Section 2 describes the related works. Section 3 describes the proposed model is made. Section 4 contains the validation strategy used. After, Section 5 the results and discussion are presented in the next section. Finally, Section 6 specifies the conclusions and future work.

II. RELATED WORKS

For the review of the literature, the PICO methodology [7] was applied, where three keywords were chosen (Academic Management, Competence Development, Secondary School Students) related to the present investigation. Based on these 3 keywords, the following 4 research questions were formulated: (Q1) What methodologies / method / technologies / tools are used for academic management in students? (Q2) What kind of tools/techniques does academic management use to measure competencies? (Q3) What are the techniques/models/methodologies/tools/architectures that are used to guarantee the development of competencies in students? (Q4) What techniques / models / methodologies / tools /

architectures can be used in academic management to ensure the development of skills in students?

Subsequently, the information search was carried out in repositories such as Web of Science, IEEE Xplore and Scopus. Only articles from scientific journals, published as of 2018, in English and Spanish were selected. Subsequently, the most relevant articles for this research were selected (TABLE I).

TABLE I. IDENTIFIED CATEGORIES

Categories	Reference	Quantity
Academic Management (Q1)	[8], [9], [10], [11], [6], [3], [12], [13].	8
Performance Measurement (Q2)	[14], [4], [5], [15], [16], [17], [18], [19].	8
Improvement of Learning (Q3)	[20], [21],] [13], [22], [23].	5
Development of Competences (Q4)	[24], [25], [26], [27].	4

A. *Academic management*

Four tools used by students for academic management were identified (TABLE II). One of them is the use of asynchronous classes. Ryan et al. [10] mentions that the recorded sessions contribute to the learning of university and high school students. Likewise, sessions on digital platforms are more efficient in the educational process, since they enrich performance [6], [12] and allow better participation during classes [13].

Spyropoulou et al. [3] mentions that it is possible to increase the interest of students by making use of smart devices such as desktop and mobile computers.

Likewise, these devices with the use of the Internet can give access to different information repositories [9] and virtual evaluations [8] compared to traditional education. On the other hand, it also gives the possibility of tracking, monitoring, and better assistance during learning [6], [12] In an investigation it was shown that the use of Trello brought the improvements explained above compared to conventional teaching [4].

TABLE II. IDENTIFIED TOOLS FOR ACADEMIC MANAGEMENT

Tools for Academic Management	Reference
Asynchronous classes	[10], [6], [12], [3]
Smart devices	[8], [9], [6], [3], [12]
Digital platforms	[8], [11], [6], [12]
IoT devices	[6], [3]

B. *Competence measurement*

Three tools were identified that are used by students to measure competencies (TABLE III). Mixed linear models are used for the analysis of student behavior for the selection of a link on the Internet. Through the algorithm it was possible to analyze the reading capacity of the students [14]. In other investigations, the classification and regression tree (CART) is used to analyze the responses of students in the 2015 PISA test. In this way, it is possible to classify according to their performance and factors that influence their performance [4]. Likewise, other authors used Machine Learning to analyze the relationships between psychological and demographic dispositions and mathematical competence using data from the 2012 PISA test [18].

In other investigations, the use of different academic activities was also identified. In schools, mathematical exercises are used through the use of serious games for students, since it is possible to see the development of a competence using the data generated by the games [5]. Critical thinking activities are also used, since it allows creativity to be measured [15]. Likewise, online tests were used, since it allows greater possibilities for the analysis of the generated data [16].

Statistical analysis, on the other hand, allows finding relationships between student performance and complex variables, through factor analysis [17] and statistical analysis [19]. Both demonstrate effectiveness. However, factor analysis requires more complexity than statistical analysis.

TABLE III. IDENTIFIED TOOLS FOR COMPETENCE PERFORMANCE MEASUREMENT

Tools for Competence Performance Measurement	Reference
Algorithm	, solol[14], [4], [18]
Educational activity	[5], [15], [16]
Statistical technique	[17], [19]

C. *Improve learning*

Three tools that are used in students to improve student learning were identified (TABLE IV). The technique of predictive analysis were used to generate models of questions for exams [20]. In another investigation, data analysis techniques were used from questionnaires, in order to know the perception and retention of information of the students [21] [13].

The Design Thinking methodology is used to improve the educational process of students, since this technique allows them to develop artistic development skills and content understanding [22], and express themselves in a more personal way [23].

TABLE IV. IDENTIFIED TOOLS FOR IMPROVEMENT OF LEARNING

Tools for Improvement of Learning	Reference
Questionnaires	[20], [21], [13], [22]
Analysis of data	[20], [21], [13]
Design Thinking	[22], [23]

D. *Competence development*

Four tools were identified that are used in students for the development of competencies (TABLE V). An investigation affirms that the use of electronic devices contributes to student learning and allows for better results [23] [24] [25] [26], since it allows the use of tools such as evaluations and learning methodologies [24] [25]. Other authors propose a research methodology that allows overcoming academic barriers and promotes cognitive access to scientific education [26] [27].

TABLE V. IDENTIFIED TOOLS FOR THE DEVELOPMENT OF COMPETENCES

Tools for the Development of Competences	Reference
Electronics devices	[24], [25]
School activities	[25]
Aplication	[26]
Methodology	[25], [27]

III. Proposed Model

The development of the model proposed in this research was divided into 4 phases (Fig. 1): (1) Selection of the methodology and technique. (2) Study material design. encompasses in the definition of the study material of the system. (3) Design of evaluations, the third phase consists of acquiring a bank of questions to generate evaluations. (4) Design of the tool, in the fourth phase the previous elements are integrated into a useful system, the necessary functions, modules, actors and technological elements are defined.

In phase 1, a compilation of educational methodologies and techniques is made, to later be compared with each other with specific criteria. In phase 2, the criteria for validating the educational material for students are defined and, using these criteria, the available study material released by the OECD is compiled and classified. In phase 3, the criteria for the classification of questions by area, themes and sub-themes are investigated. Then, evaluations and questions released by the OECD are collected and more are written to generate the question bank. Finally, in phase 4, the educational process is analyzed to find the needs of the business process, the logical architecture of the application is designed.

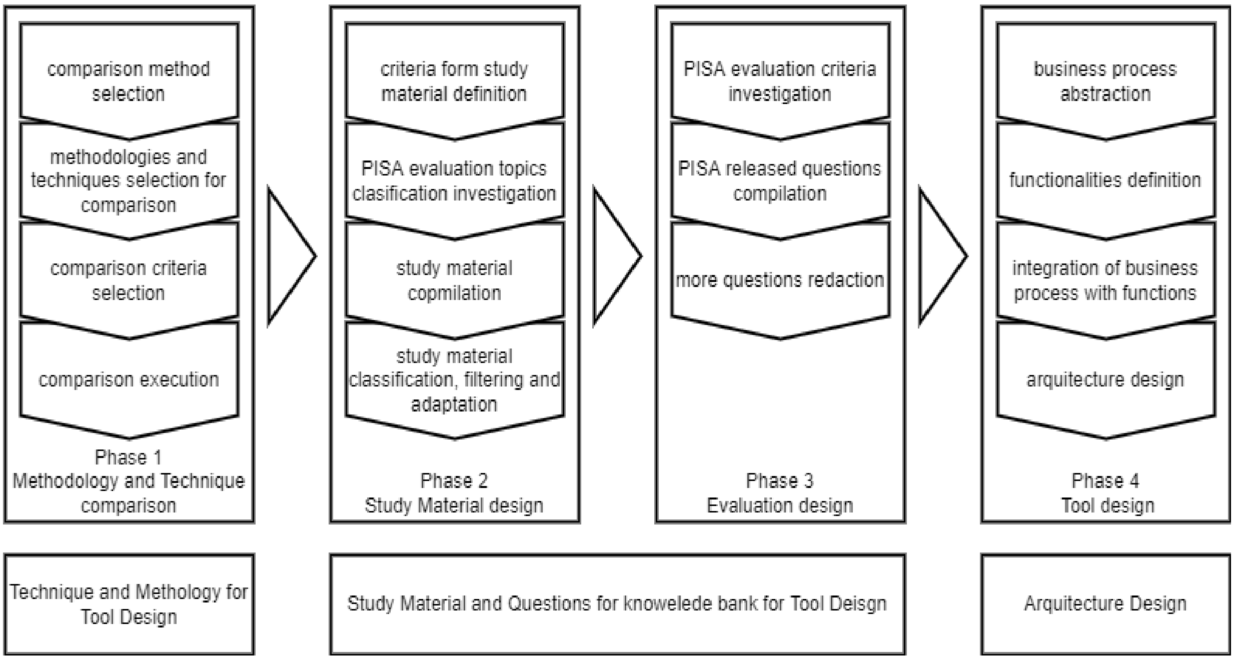

Fig. 1. Phases of the research and development of the model

A. Phase 1: Education methology and technique selection

The objective of this phase was to decide what the methodology and technique that our model will use will be. The steps followed are the following:

1) *Priorization matrix:* Choice of the prioritization matrix as a tool to be used for benchmarking. This method was chosen to effectively benchmark by evaluating each criterion in relation to its relevance to selection. This process consists of evaluating the importance of each criterion relative to each other. In this way, the relevance of each criterion will be directly proportional to the number of other criteria on which it has influence.

2) *Comparison items selection:* A search was made for articles that support teaching methodologies and techniques. Where Round Table [28] Visual Thinkin [29] and Learning Management System (LMS) [30] were selected as techniques and Project-Based Learning [31], Electronic Learning (E-Learning). [32] and Blended Learning (B-Learning) [33] as methodologies.

3) *Comparison criteria selection*: The criteria were selected based on those used by [34] for the methodologies comparison, and by [35] for the techniques comparison.

4) *Score calcultacion:* According to the score for each criterion, the score for each item was calculated (TABLE VI and TABLE VII), where the score for each item is on a Likert scale (1 = Very low and 5 = Very high).e

TABLE VI. Teaching Methodology Benchmark

Criteria	Impact	Teaching Methodologies					
		Project Based Learning		Electronic Learning		Blended Learning	
		Score	Average	Score	Average	Score	Average
Learning resource	17%	2	0.34	4	0.68	5	0.85
Evaluation method	17%	2	0.34	4	0.68	5	0.85
Information Management	17%	2	0.34	5	0.85	5	0.85
Medium of Interaction	13%	4	0.52	3	0.52	5	0.65
Ease of usage	17%	3	0.51	4	0.51	4	0.68
Platform	19%	3	0.57	4	0.57	5	0.95
Total	100%	16	2.62	24	3.81	29	4.83

TABLE VII. TEACHING TECHNIQUES BENCHMARK

Criteria	Impact	Teaching Techniques					
		Round Table		Visual Thinking		Learning Management System	
		Score	Average	Score	Average	Score	Average
Content transparency	9%	3	0.27	4	0.36	4	0.36
Content structure	18%	2	0.36	3	0.54	5	0.90
Cooperation and communication	14%	2	0.28	1	0.15	5	0.70
Technology	18%	1	0.18	3	0.54	5	0.90
Didactic	31%	3	0.93	4	1.24	4	1.24
Administration tools	18%	0	0	0	0	5	0.90
Total	100%	12	2.02	15	2.83	28	5

B. Phase 2: Study material design

For this process, (1) it was first investigated which areas of knowledge PISA assesses and which topics are classified in each area. (2) Later, it was investigated if there are criteria that subclassify the areas, to be listed later (Phase 3: Evaluation design

To carry out the evaluations, we (i) investigated the evaluation method of the PISA tests, that is, it was identified how and how the questions are adequately evaluated. (ii) Released questions from PISA assessments were collected [36]. Finally, (iii) more questions were written until a consistent question bank.

C. Phase 4: Tool design

This tool is designed using JavaScript as the programming language and it is composed of 2 components, that is, the logic component and the visual component hosted in the cloud. To use the application, a desktop or mobile device (preferably a desktop device), a browser and an internet connection are required (FIG. 2).

The users that were considered as actors in the architecture of the application are teachers and students. The functionalities for the teacher are the generation of reports, consultation of study material and the generation of evaluations. On the other hand, the functionalities for the student are evaluations, practice exercises and educational material. In addition, the app composes an authentication function to allow access to only the user determined for each role.

TABLE VIII). Once the criteria were defined, (3) a compilation of study material and questions released by the OECD from past PISA assessments was made. (4) Finally, the content was classified, filtered and adapted in a format so that children can understand and study. The result of this process was 30 documents in PDF format of solved exercises.

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TABLE VIII. AREAS, TOPICS, AND SUBTOPICS OF PISA EVALUATIONS

Knowledge area	Classification (Topics)	Subclassification (Subtopics)
Science	Biological Sciences	Frontiers of science, environment, natural resources, and health
Science	Earth and space sciences	Frontiers of science, environment, natural resources, and health
Science	Physical	Natural resources and health
Science	Chemistry	environment and health
Mathematics	change and relationships	Arithmetic and Algebra, Descriptive Statistics
Mathematics	Quantity	Functions and Graphs
Mathematics	space and shape	Space geometry, Plane geometry
Mathematics	Probability	Combinatorics, Probability
Reading	continuous prose	Global Understanding, Interpretation and Integration, Reflection and Assessment
Reading	discontinuous prose	Interpretation and Integration, Reflection and Assessment
Financial education	money and transactions	money and transactions
Financial education	financial overview	financial overview
Financial education	Financial planning and management	Financial planning and management
Financial education	risk and benefit	risk and benefit

TABLE IX. QUESTION NUMBER PER AREA AND TOPIC

Knowledge area	Classification (Topics)	Question quantity
Science	Biological Sciences	32
Science	Earth and space sciences	19
Science	Physical	10
Science	Chemistry	13
Mathematics	change and relationships	16
Mathematics	Quantity	2
Mathematics	space and shape	5
Mathematics	Probability	5
Reading	continuous prose	18
Reading	discontinuous prose	6
Financial education	money and transactions	7
Financial education	financial overview	4
Financial education	Financial planning and management	3
Financial education	risk and benefit	6

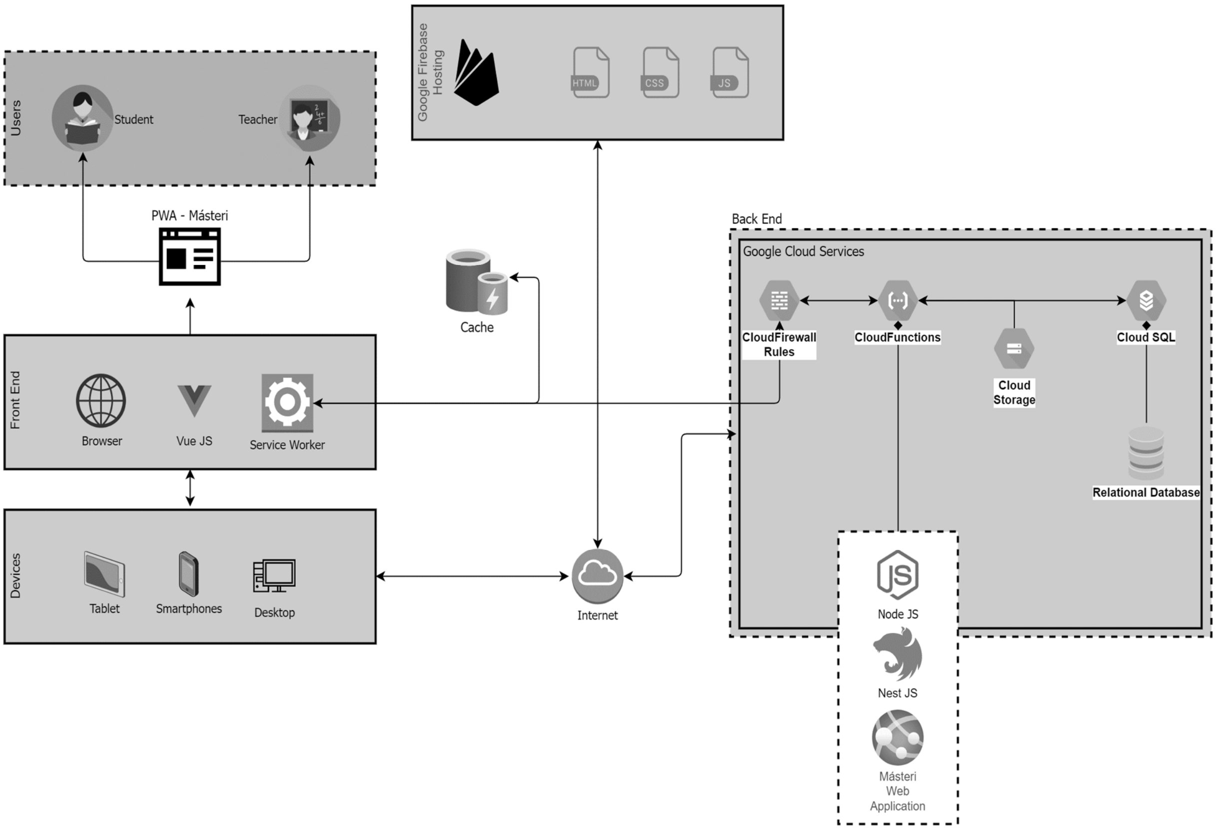

Fig. 2 Solution arquitecture

IV. VALIDATION

The validation of this study was carried out in 3 experiments aimed at: (i) teachers' perception of "usability", (ii) students' perception of "usability", and (iii) the "effectiveness" of the application in improving student performance.

A. Experiment 1

For the sample, a group of 15 secondary school teachers from different educational institutions in Peru was selected. The process consisted of holding a videoconference via Google Meet where a demonstration of all the functionalities of the application was carried out for the teacher user. Afterwards, the link of the usability survey was sent to the teacher, which consists of 5 questions (TABLE X), on the Google Forms platform [37].

The first question had the objective of knowing the opinion of the users about the system through a Likert scale (1 = Very Bad and 5 = Very Good). The other questions, on the other hand, were closed-choice questions and were aimed at knowing the appreciation about the characteristics of the system.

B. Experiment 2

The experiment was carried out on 2 occasions. (i) In person, at one private educational institution in Lima, Perú above and the sample was obtained from volunteer students from the 4th and 5th year high school classrooms, which resulted in a total of 38 participants. (ii) Remotely, through a meeting using Google Meets attended by 22 students between the 4th and 5th years of secondary school.

TABLE X. QUESTIONS FOR THE TEACHER SURVEY

Code	Question	Options
Q1	According to what was shown, how did you think about Master?	Likert
Q2	Does the *Másteri* application seem intuitive to you?	Yes/Maybe/No
Q3	Does the *Másteri* application seem useful to you when tracking your students?	Yes/Maybe/No
Q4	Do you find the study material useful for the students?	Yes/Maybe/No
Q5	Would you recommend the use of the *Másteri* application?	Yes/Maybe/No

TABLE XI. QUESTIONS FOR THE STUDENTS SURVEY

Code	Dimension	Question	Options
Q1	-	According to what has been shown, how did you like the *Másteri* application?	Likert
Q2	PE	Using the *Másteri* app allows me to learn easily and efficiently.	Likert
Q3	PE	Using the *Másteri* application seems beneficial for my learning.	Likert
Q4	EE	Using the *Másteri* application is simple and intuitive.	Likert
Q5	SI	I find the *Másteri*'s learning material useful and informative.	Likert
Q6	BI	I feel that I can increase my knowledge after using the *Másteri*'s resources.	Likert

This experiment was carried out in 2 steps, (i) demonstration of the application's functionalities and (ii) development of a survey through a Google Forms form [38]. The survey was composed of a general question about the appreciation of the system and 5 questions based on the dimensions of Performance Expectancy (PE), Effort Expectancy (EE), System Information (SI) and Behavioral Intention (BI) of the UTAUT model [39] (TABLE XI).

In carrying out the experiment in person, a demonstration of the use of all the functionalities of the application was made in the classrooms of 4th and 5th year of Secondary. The navigation system, the study material, the practice tool and the student profile were detailed. Next, it was requested that, voluntarily, the students answer the usability survey through a mobile device provided by the exhibitor.

To carry out the experiment remotely, the demonstration was carried out by sharing the exhibitor's screen in a Google Meets meeting, where each functionality of the student user's application was detailed. The development of the exhibition was similar to the face-to-face demonstration. At the end of the demonstration, the survey link was provided to the participating students, and they were instructed on how to complete the survey.

C. Experiment 3

The experiment was carried out remotely, where a total of 4 students participated, from different public and private schools in Lima, between 14 and 16 years old belonging to the 4th and 5th years of secondary school.

The application validation process is divided into 3 phases, where the initial phase includes the selection of the sample of students between 14 and 16 years of age and the acquisition of participation permits by the minor's guardian. Next, a meeting was held and the application was demonstrated to a group of 4 students through the Google Meets tool.

The test phase consists of granting a *Másteri* user account to the students so that they can make use of the functionalities for 1.5 weeks. Period in which they will use the application without restrictions.

The results phase includes carrying out a final evaluation and comparing the performance of the 2 exams in order to identify the percentage of improvement after using the application.

With the information from the evaluations, the percentage of performance improvement (IR) will be obtained with Eq. (1), where the score of the first exam is represented by the initial score (IS) and the score of the second exam is represented by the last score (LS).

$$IR = \left(\frac{IS-LS}{LS}\right) \times 100\% \quad (1)$$

V. RESULTS AND DISCUSSION

In Fig. 3 and Fig. 4, the results of experiment 1 are shown, where the teachers' appreciation of the "usability" of the application was evaluated.

In Fig. 3, in relation to the predominant assessment of the application (Q1), 73.3% of the teachers gave a "very good" rating (5).

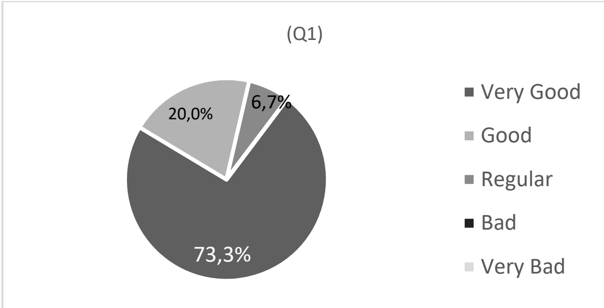

Fig. 3. Results from Q1 question from the teacher survey

On the other hand, FIG. 4 shows the results of the questions about specific aspects of the application (Q2-Q5). The results of questions Q3 and Q5 are all "Yes", which means that all the respondents found the application useful (Q3) and recommendable (Q5). In addition, the questions about whether the application has an intuitive design (Q2) and quality content (Q4) present 93.3% (14 votes) as "Yes", indicating that these aspects have opportunities for improvement.

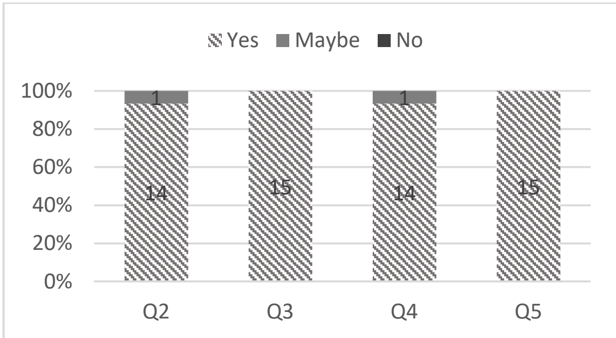

Fig. 4. Results from Q2-Q5 questions from the teacher survey

In FIG. 5 and Fig. 6, the results of experiment 2 are shown, where the appreciation of the students about the "usability" of the application was evaluated.

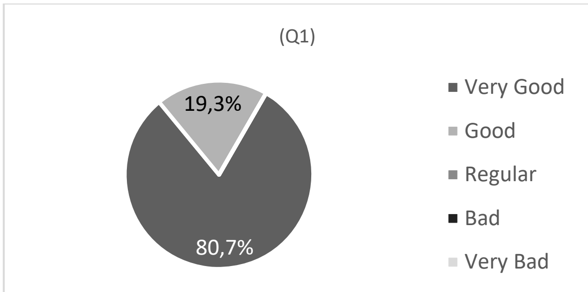

Fig. 5. Results from the student survey

FIG. 5 shows the answers on the general opinion (Q1), where 80.7% of the students gave a "very good" rating (5).

On the other hand, Fig. 6 shows the results of the questions on the UTAUT dimensions, where the results are predominantly positive, that is, scores greater than the upper fourth (4.00).

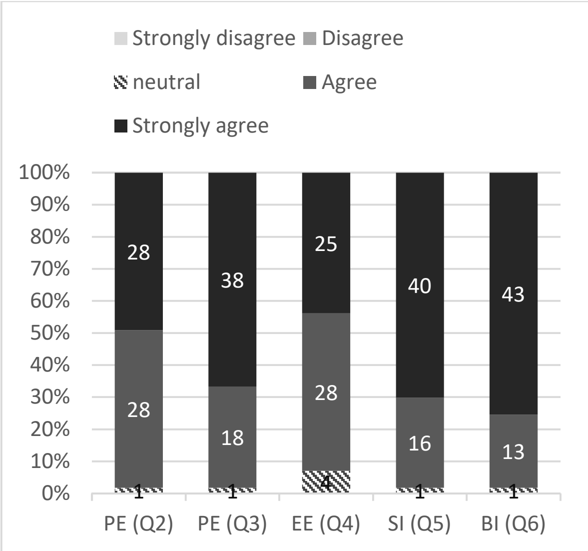

Fig. 6. Results from Q2-Q6 questions from the student survey

In Fig. 6, it is observed in the results that the Behavioral Intention dimension (Q6) presents an average score of 4.74, which is a positive score that indicates how students are willing to use it for their learning.

On the other hand, the results of the Effort Expectancy dimension (Q4) present an average score of 4.37, which is a positive score, but significantly lower compared to the other dimensions. This means that the application is perceived as complex for some users.

The results of experiments 1 and 2 indicate that the application is perceived positively by most users. Even so, questions Q2 and Q4 of exp. 1 and Q4 of exp. 2, agree that navigation and educational material have aspects that could be improved.

The results of experiment 3 (TABLE XII) show the results of the evaluations carried out before and after giving the students the *Másteri* accounts, where the grades are presented as percentage. The average performance of the students in the first exam is 57.1%, while the average performance of the second exam is 83.9%. This fact reflects how the application improves student performance by 46.7% on average, and in a minimum of 40.0%.

TABLE XII. RESULTS OF STUDETNS' PERFORMANCE EVALUATION

Student	Exam 1	Exam 2	Comparison
Student 1	64.3%	92.9%	44.4%
Student 2	71.4%	100%	40.0%
Student 3	35.7%	50%	40.0%
Student 4	57.1%	92.9%	62.5%
Average	**57.1%**	**83.9%**	**46.7%**

VI. CONCLUSIONS AND FUTURE WORKS

Various works have been done on the use of educational technologies in children, especially using the gamification approach, such as [5]. and some have conducted analyzes of PISA assessment results [4] [40]. However, these tools have not yet been applied to generate development specifically in the competencies assessed by PISA.

In this research, a model based on a B-Learning approach was proposed to monitor the competencies of the PISA test. The proposal was made in 4 phases: (i) Selection of the methodology and technique. (ii) Design of the study material, (ii) Design of evaluations and (iv) Design of the web application. The design of the web application was based on the OECD evaluation standard, which contains educational material focused on the PISA competencies and tools to practice and measure knowledge for students. This application was made using cloud services and web development frameworks. The application architecture was designed in 3 layers and divided into teacher and student functionalities.

Two experiments were carried out with the aim of measuring the usability perceived by each type of user and one experiment dedicated to measuring the effectiveness of the application. The experiments were carried out on teachers and students from various educational institutions in Lima, Peru.

The results of experiment 1 showed that the perception of the application (Q1) by teachers is positive, where 80.7% marked "Very Good" (5). The other questions also showed positive results. Even so, a small group of teachers (6.7%) found that navigation (Q2) and content quality (Q4) present aspects that could be improved. This information indicates that for non-tech-savvy adults, the app needs to be simpler, and for some teachers, the content of the app needs to be more detailed.

The results of experiment 2 showed that the students' perception of the application (Q1) is positive, where 73.3% marked "Very Good" (5). In relation to the other questions, the strongest point is the Behavioral Intention (Q6), where the average score was 4.74. The weakest point is the Effort expectancy, where the average score was 4.37, being a positive score but lower compared to the rest. This means that, for students, the use of the application is slightly complex.

The results of experiment 3 indicate that the application can improve the performance of students in math, science, reading skills and financial literacy by at least 40%.

As future work, the integration of new areas of knowledge recognized by the OECD for the PISA evaluation, the inclusion of audiovisual and interactive content for educational material and the expansion of the catalog of practice tools for students is recommended, that is, the inclusion of new serious games that allow practicing the areas of knowledge evaluated.

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